Pilot Testing Innovative Auto ID Technologies

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The Flight Hardware Logistics Group at the Jet Propulsion Laboratory in Pasadena, Calif., has implemented a variety of innovative automatic identification technologies. By incorporating small high-density codes, local data routers, and cordless readers, the group aims to drastically improve inventory management and tracking.

It's all about keeping track of things. Driven by the need to keep track of a myriad of items ranging from chairs and desks to spacecraft payloads, the government-industry partnership in the aerospace field has led the way in implementing new automatic identification (Auto ID) technologies.

The Flight Hardware Logistics Program (FHLP) at the Jet Propulsion Laboratory in Pasadena, Calif., is currently developing and piloting several new technologies to upgrade their inventory management and tracking systems. The goal of this pilot program is to improve the configuration management process. The scope of the pilot program includes the following:

- Identify parts through labeling and permanent marking.
- Upgrade to smaller, two-dimensional symbol.
- Upgrade reader hardware – wireless.
- Improve database connectivity internally and with vendors, and subcontractors.

Fortunately, the aerospace industry, the Auto ID industry (makers of bar code equipment and the like, including radio frequency data transmission and identification equipment), and vendors from all product-related areas have been working on standards and technologies that make this daunting task feasible. The Internet provides a highly efficient transport medium for the data, and Internet-related standards for high-level program and computer independent programming languages to facilitate the process.

The following technology components are being researched or implemented within the FHLP system:

- Bar codes and two-dimensional codes.
- Data collection hardware.
- Data management software.
- Radios and radio frequency identification device (RFID).

The system can be implemented in a stepwise manner, which is a new concept. Historically, major system upgrades have required all-or-nothing leaps with substantial hardware and software integration that is essential before the plug can be pulled on an old system and a new method put into operation.

Old-Fashioned Bar Codes

Also known as *one-dimensional* or *linear* code, old-fashioned bar codes carry data using a method called bar *width modulation* – an easy way for machines to determine binary information using the analog input methods that were prevalent 30 years ago.

These simple wide and narrow striped symbols (see Figure 1), which carry between 10 and 20 bytes of data, exist on many items ranging from consumer prod-

> *"Bar codes have a capacity to carry a license plate or key to a database, but need additional information from another source to fully identify the item, and often, the appropriate database to find the information."*

ucts to fixed assets such as chairs and PCs, to doorways (location codes), to automotive vehicles (vehicle identification numbers). Here is the rub though: the method of encoding data varies and, depending on where and when the code originated, it may or may not be unique or even fall into a recognizable category.

Fortunately, standards have been in place for nearly three decades that describe the method of encoding the information, and modern bar-code readers can quickly decide which method of encoding was used and the content of the data encoded. The bar code crowd refers to this as *automatic discrimination*. Bar codes have a capacity to carry a *license plate* or key to a database, but need additional information from another source to fully identify the item, and often, the appropriate database to find the information.

Advanced Two-Dimensional Bar Codes

Also known as *matrix symbols*, advanced two-dimensional (2D) bar codes are a relatively new addition to the machine-readable arsenal that uses the vertical, as well as horizontal dimension, to encode information. The result is a symbol that looks like a miniature checkerboard (see Figure 2), and can encode an order of magnitude more information in the same area as a linear bar code. As a result, more information can be carried with an item, including data identifiers specifying each field of encoded data.

Designed to be read by more modern digital imaging technology, the 2D marks are rapidly showing up on everything from

Figure 1: *UPC Code*

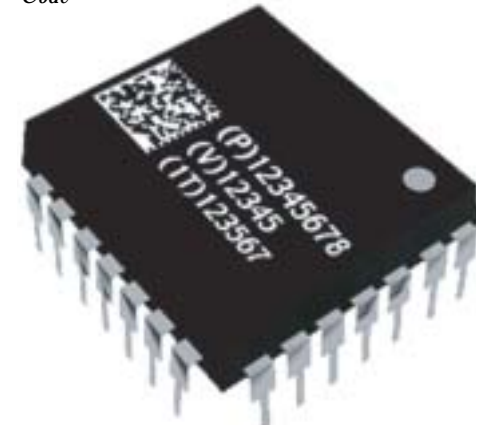Figure 2: *Advanced Two-Dimensional Bar Code*

Figure 3: *Code Corporation's Code Reader 2.0*

postage machine stamps to computer chip packages. Standards have been developed during the past decade that include data identifiers encoded along with data content, making these symbols, literally, miniature databases that travel along with an item, with from 60 to several hundred bytes of data typically encoded.

Along with the advantages of this plethora of information, however, come some major integration issues with computer systems that need to access this information. The standards for encoding this information have been driven by the industries that need better ways to interchange data. These have included the electronics industry represented by the Electronics Industry Alliance, the automotive industry represented by the Automotive Industry Action Group, the telecommunications industry represented by the Telecommunications Industry Forum, the transportation industry that has coordinated activities through the American National Standards Institute (ANSI), and which represents all of the above, and others, to the ISO.

Critical to these activities has been the creation of the aforementioned data identifiers, which are collected, numbered, and identified by the ANSI Materials Handling (MH) 10.8.2 standard [1]. While this creates a reference point for data identifiers, it also is continually being updated. For example, if two trading partners wish to send each other information on shipping cartons, they can do so using ANSI MH10.8.2 standard matrix codes. Within the matrix codes, part numbers carry a data identifier, followed by the actual part number. Additional data elements such as production date or purchase order carry their own unique data identifiers. Each label on a shipping carton becomes its own database providing the receiver with all or much of the information needed to receive the shipment and keep track of it.

The creation of new data identifiers is an ongoing process, and synchronizing systems with new data is a daunting, ongoing maintenance activity.

These matrix codes use field separation sentinels to handle variable length data encoding and have built-in forward error correction using Reed-Solomon principles[1] for forward error correction that have since been deployed in everything from disc drives to deep space probe radio transmissions.

In basic terms, in addition to the data, additional information is sent with the data to detect any errors and correct them by mathematically reconstructing the information. This is an important feature due to the high probability of partial damage to labels and permanently marked symbols during the shipping, constructing, mission, and recovery processes.

"Each label on a shipping carton becomes its own database, providing the receiver with all or much of the information needed to receive the shipment and keep track of it."

Bar-Code Readers Become Mini Digital Cameras

There are many types of bar-code readers deployed in millions of locations around the world. The technologies used for reading bar codes always involve the use of light, since bar codes are an optical technology. Machines must be able to see the codes in order to derive the data from them. The sensing equipment always involves a light source, a method of interrogating the light reflected from the object with the bar code on it, and an electrical circuit that translates the light-and-dark patterns into digital information for a receiving computer.

As bar codes have become more diverse and complex, the automatic identification industry has responded with more complex systems, which have deployed moving laser beams, charged-coupled devices, microprocessor chips, and most recently, complimentary metal

oxide semiconductor camera sensors controlled by powerful micro computers with tremendous calculation processing capacity (see Figure 3). The industry has benefited from the consumer products that have driven the costs of these components downward, including compact disc players, digital cameras, and Internet-capable home computers. Cellular phones have added cheap and reliable miniature rechargeable batteries and low-cost digital radios. The overall electronics industry supplies memories, keyboards, switches, displays, and connectors.

The latest generation of bar-code readers includes palm-sized devices that can read and decode any matrix or linear symbol and transmit the information over a local radio connection to a host computer, which is typically a client operating within a broader LAN or WAN. The host uses the Internet to communicate transactions over the World Wide Web to other trading partners, and high-level, open platform programs written in XML can control all.

The latest generation of bar-code readers are small handheld devices that use digital photography and cordless data transmission.

Data Routers Send the Right Stuff to the Right Place

The routing of data between host computers has been a core element in the rapid deployment of the Internet into every aspect of modern business communications. A similar component is used in the software of client systems that accepts input from the bar code reader and then determines the proper recipient of the data elements. This is fairly simple in a rigid, linear bar-code system such as the type that exists in every modern grocery store.

At checkout, the bar-code reader sees the code on the item as it is moved over the reader in the checkout lane. The reader in the checkout lane sends the information to a computer that uses it as a key to look up the price of the item in a database, and totals the price of all items being purchased. When the buyer swipes a credit or ATM card to pay for the goods, the point-of-sale computer is smart enough to route that information to a different network that does the money transaction.

Now, imagine a palmtop computer that receives a 100-character record from a matrix bar code, including 12 different data elements followed by a six-digit location number that the bar code reader

derives from a linear code on a storage bin. The palmtop computer routes the information from the matrix code to a receiving system that generates inventory update transactions, to another computer that generates an electronic data interchange closure transaction to the supplier that shipped the system, and to the local warehouse computer that keeps track of the location of the item just received. Now multiply these transactions by the activities involved in the logistics support of a space payload, and the original problem – keeping track of things – is solved.

Ongoing Maintenance Is Mission Critical

Most systems involving commerce require a substantial, continuing maintenance effort. This maintenance effort has certainly been improved with a variety of Internet tools and the establishment of eXtensible Markup Language as an open standard for applications development. This allows Auto ID system developers the ability to pool resources to define data identifier lexicon standards.

Furthermore, tools are being developed that will analyze a matrix code, determine the data identifiers used, and then analyze a Web interface program to automatically match the data elements, requiring only the exceptions to involve further programming. What this means is that new applications can be quickly implemented in parallel to legacy operations, which can exist without being disturbed, thanks to the intelligence contained in the data router nodes.

Among the early adopters of the matrix codes and data identifiers is the Aerospace Industries Spec2000, which contains a system road map for applying intelligent data identifiers to information exchange between trading partners. In Figure 4, a developer selects Spec2000 elements for encoding and intelligent routing from a matrix bar code.

As new data elements get incorporated into Spec2000 and ANSI MH10.8.2, the requirement for periodic updates to the systems becomes evident. This is another important feature of the intelligent data routing capability. As new data elements enter the system, a simple update of the rules from a subscription service, similar to those deployed to prevent the spread of new computer viruses, keeps the new data flowing.

Radios: From Sputnik to Bluetooth

Data always needs a method for move-

Figure 4: *Spec2000 Computer Display*

ment. Many components involved in the aerospace technology are not conveniently brought to a bar-code reader. So the reader must be taken to the bar code. It was this application characteristic that created the need for small, portable data radios. While we currently take the digital radios in our pocket cell phones for granted, it was not too many years ago that this was merely a dream for applications developers.

Ten years ago, the majority of data radios used a part of the radio band that required a Federal Communication Commission (FCC) site license for each location. Data rates averaged about a hundred characters per second, and the batteries necessary to operate these radios were the size and weight of a brick. The first step toward modern cordless data transmissions was when the FCC declared several radio bands free of the need for site licensing. Deemed *ISM* – Industry, Science, Medical – these radio bands created an instant area of development for the Auto ID industry. They also attracted a number of other gadgets, ranging from cordless phones to cordless speaker systems.

With many gadgets deploying into these bands, the need for standards became paramount. The first standard, Institute of Electrical and Electronics Engineers (IEEE) 802.11 [2], was developed as a relatively high-speed (millions of bytes per second) communications scheme for use in wireless local area networks. Now deployed worldwide in mil-

lions of locations, the IEEE 802.11 standards-based products represent an excellent example of industrial competitors achieving a consensus standard for complex equipment interoperability. While 10 years ago it was discussed as a remote possibility, today, people go to the local electronics mega-store and buy IEEE 802.11 components from multiple vendors, then go home and plug-and-play wireless, nearly as simply as plugging a DVD player into a new TV set.

While the IEEE 802.11 standard works well for full-time local area networks, its requirement of session maintenance creates a tremendous drain on the batteries of portable devices. Recognizing the need for a cable replacement strategy, a new standard – designed to operate within the same radio band and coexistent with the 802.11 networks – began about six years ago. Dubbed *Bluetooth*, the new standard promised lower cordless device costs due to a number of factors, including smaller batteries. For example, the Compaq iPAQ H5450 in Figure 5 includes a 400 MHz CPU, 64

Figure 5: *The Compaq iPAQ H5450.*

MB RAM and supports both IEEE 802.11 and Bluetooth wireless communications.

Bluetooth is now becoming the de facto standard for cordless digital products with literally thousands of devices available, ranging from cellular telephone headsets to industrial computer links. United Parcel Service recently announced that, beginning June 2003, more than 50,000 Bluetooth-equipped bar code reading devices will be deployed throughout its worldwide network of computerized parcel handling systems [3]. Bar-code readers without Bluetooth as an option will soon be relegated to the has-been pile.

Direct Identification Through Radio Frequency Identification

As useful as the bar code technologies are, they are still an optical technology, meaning, simply, that the item must be seen by the reader in order to be decoded. Another relatively new technology offers an alternative, albeit far more expensive, method for cases where an item that is embedded in another item, or covered with a coat of paint or encased in rubber inside a tire, can still identify itself to the outside world. This RFID method involves a miniature radio transmitter attached to, or embedded into the item being identified.

While still very early in its evolution – there is no standard in place for interoperability of RFID systems – the technology is promising and will be deployed in future systems. While far from achieving interoperability, and therefore far from mass deployment, the ANSI committees involved with the MH10.8.2 standard are already planning for RFID within the world of data interchange. This means that existing systems with intelligent data routers will easily be adapted to these components when they begin to overcome the manufacturing standards and cost problems currently confounding the promise of this technology.

Putting It All Together

The benefits of these technologies will be available for scientists and aerospace designers for many years to come. The Jet Propulsion Laboratory, managed by the California Institute of Technology, is NASA's lead center for robotic exploration of the solar system. To support continued exploration, the laboratory is making advances in technology with new instruments and computer programs to help spaceships travel farther and telescopes see further than ever before.◆

References
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2. Institute of Electrical and Electronics Engineers. <u>The IEEE 802.11 Standard</u> <www.computerworld.com/services/ research/linkspage/0,4848,LNK 886,00.html>.
3. Brewin, Bob. "UPS to Deploy Bluetooth, Wireless LAN Network." <u>Computerworld</u>. 23 July 2001 <www. computerworld.com/mobiletopics/ mobile/story/0,10801,62459,00.html>.

Notes
1. Named after the Massachusetts Institute of Technology (MIT) scientists who developed them about 40 years ago, and first published in a five-page paper that appeared in 1960 in the *Journal of the Society for Industrial and Applied Mathematics*, "Polynomial Codes over Certain Finite Fields," by Irving S. Reed and Gustave Solomon, then staff members at MIT's Lincoln Laboratory. Reed, later a professor at the University of Southern California, consulted for the Jet Propulsion Laboratory on projects to ensure the receipt of correct data in transmissions involving space exploration, as related in the *Society for Industrial and Applied Mathematics Newsletter* in January 1993.

About the Author

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